

# VIRTUAL LABS: A COMPLEMENT FOR TRADITIONAL LABORATORIES

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**Abstract:** Science is mainly a practical activity, this is why, in the academic world, a laboratory becomes an essential element. For a long time, the traditional laboratory has been the only place for experimentation for both students and teachers. However, current technological advances allow the use of virtual laboratories. Both, traditional and virtual laboratories, show disadvantages, but also substantial advantages which justify its use. This study presents the work developed in the Classical Mechanics laboratory of the Escuela Técnica Superior de Ingeniería Aeronáutica y del Espacio (School of Aeronautics and Space Engineering), of the Universidad Politécnica de Madrid. In it, traditional didactic materials are complemented and integrated with virtual practicals which have been completely developed in a 3D virtual environment with OpenSim

**Keywords:** Virtual Lab, Physics Lab, SecondLife, OpenSim, Traditional Lab.

## Introduction and Literature Review

There is consensus among teachers that practical experience is essential for scientific learning. Although periodically its educational benefits have been questioned (Hodson, 1994), laboratories have always played a fundamental role as a learning environment in which practical work can be experienced and also practical cases may be performed (Flores et al., 2009; Saraiva-Neves et al., 2007).

According to literature, laboratory work can be seen as an opportunity to implement more active learning methods, so that students can interact more freely with their teacher and also with their peers as well as to adapt the work to the students' particular features. All this means that nowadays their use is taking on greater relevance, since the most prestigious teaching methods are those student-centered (Huber, 2008; Scheuer et al., 2006).

However, for those practicals to have a real educational value, special attention needs to be given to the kind of practical work that is offered. The first step is to have clear goals to be achieved, and then to choose a particular laboratory practical that meets those goals (Hodson, 1994).

The definition of the goals of the laboratory work has always been an essential element of discussion that is currently an active line of research (Flores et al., 2009). Although their function depends on many factors such as: the educational level, the teaching approach, the instrument for the evaluation, etc., Caamaño (2005) defines five functions for the practical work that does not contradict other authors proposals: a) *illustrative function* of concepts, b) *interpretative function* of experiences, c) *learning function* of methods and laboratory techniques, d) *theoretical research function* related to solving theoretical problems and building models, and e) *practical research function* related to solving practical problems. It is worth noting that the laboratory of Classical Mechanics where this work has been developed basically deals with the first three elements, leaving the theoretical and practical research functions for the medium-term future.

Although several of these functions can coexist within a single laboratory practical, it seems logical that a practical, whose primary purpose is to show that a particular concept is verified, is to be designed in a different way than other practical designed for training a particular technique. However, whatever the type of practical, it should be taken into account that students seem to value the cognitive challenge, that is to say, the fact that the activity is not that simple to get bored or that difficult that they cannot understand how it works (Alonso-Tapia, 2009).

Besides, current technological development has allowed going through the boundaries of traditional laboratory by using the *e-labs* or *virtual labs* in their different modalities (simulation and remote labs). Each of these laboratories has their own characteristics which gave rise to both advantages and disadvantages.

The *traditional lab* requires the equipment, the students and the teacher to be physically present at a specific location, particularly the latter for monitoring that the students' activity is properly and safely performed. It is the ideal place for experimentation because only in this type of laboratory one can directly work about the phenomena and the facts studied, and this is where the laboratory techniques are used and also where materials and measuring devices are handled in a real way. According to Rosado and Herreros (2005), it is in this student's contact with the real experiment where the main advantage of the traditional laboratory lies, since it facilitates the motivation and enhances the development of cognitive skills that are enabled.

However, it is this very fact of being real where it can also be found their major limitations. Materials and measuring instruments are often quite expensive; this fact makes it difficult for each student to perform all the tests they need. They may even have such a high cost that it could make impossible its realization. There are also some products whose handling is dangerous or even some processes that require too much time to completion, making unfeasible its incorporation into the students' syllabus.

By contrast, with *virtual labs* many of these difficulties are overcome. Some of the key advantages of these laboratories are (Berrocal et al, 2011; González-Castaño et al 2001, 2001; Rosado et al, 2003...):

- It allows performing practicals whose real experimentation otherwise would be unfeasible. When simulating a laboratory real environment using a computer system, the experiments that could not be performed, due either to their excessive cost or to their hazardous character, or even due to their duration, can currently be included in the students' curriculum.
- Lab classes become this way more flexible and the potential lab saturation due to other overlapping subjects can be avoided. Students can access the lab equipment through the browser, so that it is available 24 hours a day from anywhere.
- It is a self-learning tool with which students take the information in by trial and error learning method, because they can repeat the experiment with no limit on the number of times, and without getting ashamed when repeating the same practical, and also without fear of damaging the equipment. Moreover, they also allow providing immediate feedback on their work.
- Virtual labs also allow customizing the experiment, so that the students can alter the input variables, or set up new experiments or even choose the most significant areas in the laboratory in order to practice on certain works.

However, although virtual laboratories can be an inexpensive alternative compared to traditional laboratories, they also have their own drawbacks. Students do not use real elements, which may result in a partial loss of reality, skills, and abilities. There is also a risk that students behave as a mere passive spectator (Torres, 2014). To avoid this, it is necessary that virtual labs are accompanied by an outline where the objectives, the concept to be

analysed, the underlying equations provide a guide to the students on the procedure to follow for performing the experiment in an ordered and progressive manner (Rosado et al., 2009).

Finally, while it is true that *virtual labs* are a new alternative for teaching with very positive aspects of learning (Dormido et al., 2000; Lin, 2005), it should be clear that a *virtual lab* is different from a *real lab* or a *traditional lab*, so that their purpose should not be to replace the real labs or compete with them. They just represent another tool for teachers which open new learning perspectives (Torres, 2014).

The work has been developed in the aforementioned framework with the main aim of improving the Classical Mechanics Laboratory through the integration of real and virtual practicals. This virtual lab, fully developed in OpenSim, has been funded by the Universidad Politécnica de Madrid (UPM) within the Vice-Chancellor Call for Proposal on May, 27<sup>th</sup> 2013 for the development of virtual labs.

## **New Lab description**

The laboratory is integrated in the subject of Classical Mechanics in the Aerospace Engineering Degree which is taught in the Escuela Técnica Superior de Ingeniería Aeronáutica y del Espacio (ETSIAE) (School of Aeronautics and Space Engineering) within the UPM. This subject is located in the first semester of the second year of the four-year degree and the number of students to perform these practicals is over 600.

In each lab session only 22 students can access, as there are only 11 positions and they usually work in pairs. The high number of students, linked to the shortage of available equipment and the requirement of performing all those practicals within a period of two and a half months, causes a great saturation problem in the real lab. This led to reduce to one the number of practicals each pair of students has to perform and besides, it is not possible to coordinate classroom theory and the development of practicals activity.

The practical each pair of students executes is different, depending on the equipment being assigned when making a random distribution into groups of two. Currently there are available five Maxwell's wheels, three gyroscopes, a flywheel, a torsional oscillations piece of equipment and a rotational dynamics piece of equipment.

Although the specific activity to be carried out is the one corresponding to each team, the procedure to follow during lab sessions is similar for all those practicals. In order to avoid the students following up different steps for getting some results in a mechanical way, they are given a practical outline in which the objectives of the experiment are laid down and theoretical concepts and mechanics equations are briefly explained. Next, teachers guide them on the process of data collection. This will later allow them to calculate the value of the magnitude they are being asked. All practicals require them to obtain, in an indirect way, the value of a particular magnitude from at least two different procedures, so that they can compare them and further deepening the scientific method.

To assess lab work, students are asked to write down a complete and thorough report that has to be submitted to their teacher within two weeks. The mentioned report is not a document to fill in figures or tables or a form where the students have to answer some questions, but it is a report they have to elaborate from scratch, where they have to select and organize all the content. To do this, if they have any queries about it, they may ask their teacher, but they also have available the following support material: an error calculation manual, a description of the minimum lab report contents and an example of a report of a different practical, an assessment rubric for their lab report and a self-assessment outline that has to be filled in before the final version submission.

Previous years experience shows that the preparation of a correct report presents many difficulties for them. This is way some group tutoring sessions are organized a week after the corresponding lab session, where the students take their draft report (that has to be previously submitted to their teacher). During this group sessions all arising doubts are discussed and clarified both on an individual basis as well as in the form of group work. With this information, students write down their final lab report which will be assessed and will be part of their final grade.

Among the functions defined regarding labs, according to Caamaño, with such practices and using this type of work the aim is to enable students to *visualize* some of the concepts of the subject, to reflect and *interpret* the underlying causes or elements from the observation of the experience, *learn the lab methods and techniques*, and also they should be able to process all this information and gather it in a clear and scientifically valid document.

However, as only one practical has been proved to be insufficient and, given the problem of lab saturation, it was decided to exploit the potential of VL for all students so that they have to do at least two practicals.

As virtual practical it was chosen the *gyroscopic effect* because it is a complex and unintuitive concept with real practical applications such as flying helicopters that are highly motivating for aeronautical engineering students. Although students who were assigned the gyro practical in the real lab will work on the same concept, the purpose and the way to be tackle are different. In the real practical, they always work with the same object or rotor on which, under certain motion conditions, the gyroscopic effect appears. Their task is to vary some parameters of the movement and to measure the effect it has on others. From these direct measurements and from the equations governing the motion they obtain, indirectly, the moment of inertia of the rotor (Figure 1).

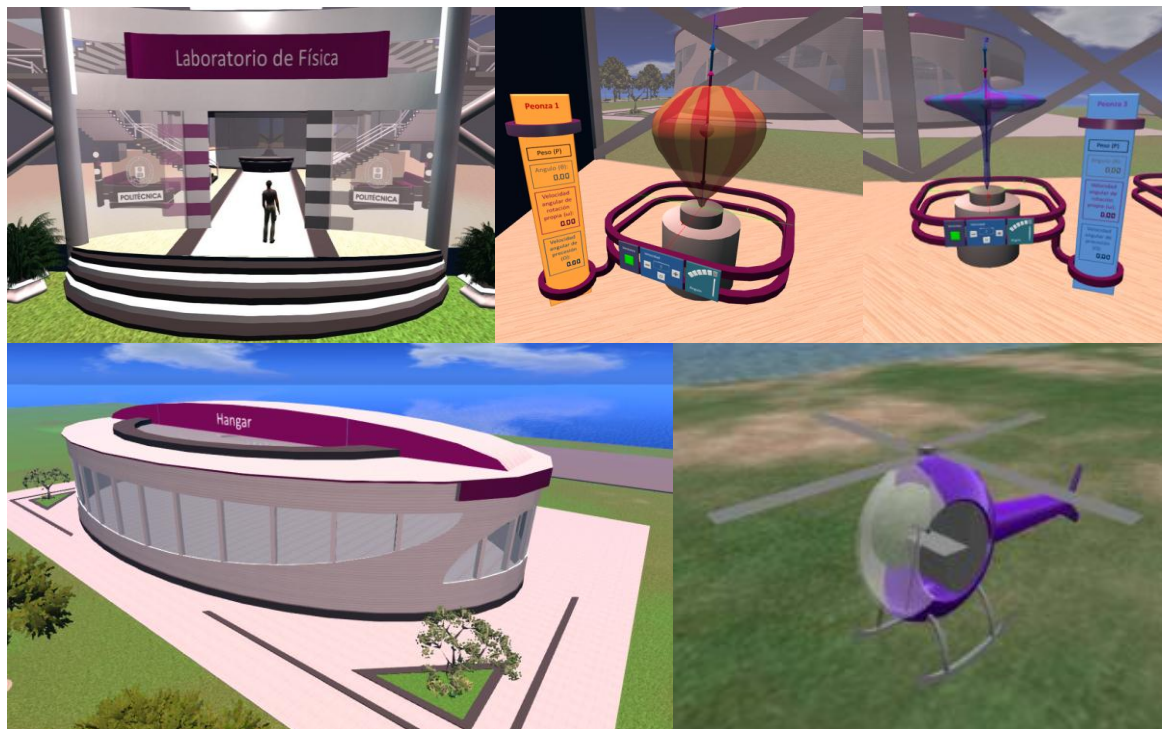


**Figure 1.-** Gyroscope (Traditional Lab)

*Virtual labs: a complement for traditional laboratories*

In the virtual practical (Figure 2), as it can be seen below, the main purpose is to illustrate and deepen the concept of gyroscopic torque, analysing the variables involved and observing its effect on it. To do this, students manipulate various parameters of several real objects which change the movement and therefore the gyroscopic effect. Finally they are asked to transfer this knowledge to a real practical situation as in the case of piloting a helicopter.

This virtual lab of Physics is integrated into the Experimental Platform for Engineering and Architecture Studies within the UPM (PEIA-UPM). It has been completely designed in a 3D virtual environment using the OpenSim open source system, because maintaining an educational scenario with SecondLife is very expensive. In this virtual world, students use an avatar, which they have previously created, to explore the world and to carry out the proposed activities.



**Figure 2.-** Virtual Lab images

Into this "scenario" of the virtual lab of Physics, it can be found a room with a virtual screen where basic theoretical concepts like the motion of a gyroscope are shown. Then, they can go to another room where there are several spinning tops with different geometry and materials which can be selected and where the values of the certain parameters that affect their movement are plotted. By pressing some buttons, the student chooses which magnitudes he/she wants to display (those are shown as coloured arrows) and it can be seen the parameter changes in magnitude and direction. It also can be obtained a graphic that you can

use to compare the each spinning top performance. From this information, the student is asked to answer a series of questions related to the concept of the gyroscopic effect. In each of them, after their answer, an immediate feedback is provided. It should be noted that the questionnaire is quite short; students are required to answer only four questions that randomly appear from a much broader database. Thus, if they decide to repeat the activity/task, they will find new elements of learning.

Once they have completed this activity, they are offered to move to a hangar where they receive instructions regarding the consequences of the gyroscopic on the helicopters movement. Finally, they are asked to 'pilot' a helicopter while they follow certain routes (previously established either by their teacher or by themselves). In the near future, students' competitions will be implemented. Only if they know and apply the principles of gyroscopic effect they will get it. It is worth noting that, although students are free to decide what they want their avatar to do, they have an outline available through the whole activity, to which they have access whenever they want. This is a card provide information about the performed tasks and the ones outstanding.

After this practical, students are not required to make a report; they only have to deal with the concept of gyroscopic effect, in a creative and innovative manner. The grade they are assigned is pass or fail, but without numerical rating. Thus the pressure they may be under is removed and the students are encouraged to "play" freely. In this initial experience phase, this is especially important because it is required the information students can provide in order to validate and improve the practical.

## **Conclusions**

The theoretical study of science and the laboratory work are two interrelated activities leading to the construction of learning in a reflective and interactive way. Both are needed. A student who lacks the appropriate theoretical knowledge will neither know how to take a measurement or observation nor how to interpret them. Furthermore, the practice of science is the only way of doing science and experience science as an act of investigation (Hodson, 1994).

The computers have been used in education for more than thirty years, as well as in the experimentation field. There are experiments that are too difficult to perform, too expensive, too time-consuming or even dangerous. Virtual laboratories can overcome these difficulties and these activities may be designed so that they better facilitate the conceptual development better than traditional laboratories. With simulations, students spend more time handling ideas as a means of building knowledge and they receive immediate feedback.

However, while it is true that virtual labs are a new tool for teaching with a remarkable motivating power, we should also note that they entail a partial loss of vision of reality and skills, so the student becomes a passive spectator. Hence, against those who claim that VL can be an alternative to traditional laboratories, we believe that they simply are a valuable complement, but they will not replace or compete with real laboratories. They open new learning perspectives that cannot fully explore in a traditional lab.

In this line of work, we have developed this virtual laboratory that allows us to improve our students' learning. As teachers, we feel the responsibility of promoting this type of creative activities and also to disseminate the results in the near future.

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